Draft – Cow Palace Used as Example

Appendix A – Data Quality Objectives for the Irrigation Water Management Plan

Step 1: State the Problem	*Description of the Problem:* Section III.F.2 of the Consent Order (CO) Scope of Work (SOW) requires the Cow Palace Dairy (Dairy) to develop and implement an irrigation water management plan (IWMP) that describes "flow metering to measure the volume of liquid applied to specific fields, and the installation of electronic sensors at the bottom of the root zone in each application field to provide for automatic shut off of the irrigation system to minimize water movement below the root zone." In order to ensure that management of irrigation of the application fields occurs in a manner that minimizes the potential movement of irrigation water below the root zone, a method to monitor soil moisture conditions and irrigation water application volumes and rates is required. The monitoring method must provide sufficient measurement coverage to account for different soil types, topographic conditions, and irrigation application methods and techniques employed in each irrigated field. *Conceptual Model:* Irrigation of crop fields is performed to provide the moisture required for crop growth. Each crop has unique water requirements to achieve maximum yield based on precipitation and soil conditions. The under-application of water can result in diminished yield or failure of the crop. Over-application of water can also result in reductions in yield and crop failure, but may also result in the infiltration of excess irrigation water below the crop root zone. Careful and planned administration of irrigation water on crop land is required to maximize crop yields and to minimize potential losses of water to the subsurface below the root zone. The stage of plant growth, crop water needs, and soil properties (water holding capacity and infiltration rates), and topography control the amount of water that may be applied to application fields without the resultant migration of irrigation water below the root zone of the crop. Effective irrigation water management results in crops that receive the appropriate amount of water to achieve yield expectations and minimizes the potential for water movement below the root zone. *Irrigation System Descriptions:* A brief description of the various irrigation methods employed at the Cow Palace Dairy are provided below: • Center Pivot – Method of crop irrigation where a long segmented arm revolves around a pivot that delivers water through a system of sprinklers located along the arm. The size and application rate from sprinklers along the arm are designed to ensure that overall application rates across the irrigated area are equal at the segmented arm revolves (smaller sprinklers/lower application rates at the center and larger sprinklers/higher application rates toward the outer radius). • Linear – Method of crop irrigation where a long segmented arm (same

	look as a center pivot) moves in a lateral or linear fashion across a field that delivers water through a system of sprinklers located along the arm. Sprinkler sizes and application rates are generally the same across the length of the linear arm to ensure equal application rates. • Wheel Line – Method of crop irrigation where long individual pipes, with large wheels and sprinklers attached, are connected to form a long “wheel –line” that is moved laterally across a field, similar to linear irrigation. • Reel Gun – Method of crop irrigation where a traveling gun (large sprinkler) attached to a wheeled cart is placed in one location in the field and then gradually pulled back into a large hose reel. The reel is placed in designated areas to be pulled across field sections. • Rill – Method of crop irrigation where intentionally created ditches are formed to carry water from a head ditch or metered pipe. The water flows down the ditch to a collection basin or drain ditch. *Planning Team:* The IWMP was developed by a team of scientists and engineers using the systematic planning process. The planning team included the Dairy staff, a professional irrigation consultant, scientists, and engineers. The IWMP data quality objectives (DQOs) generated using the systematic planning process were shared with EPA for review, input, and approval prior to completion and finalization of the IWMP. *Resources and Schedule:* The IWMP was developed in the summer/fall of 2013 and is scheduled for implementation by the Dairy upon approval by EPA. It is anticipated that the IWMP will be fully employed prior to the initiation of irrigation activities during the 2014 growing season.
Step 2: Identify the Decision	*Principal Study Question:* Is the scientific method for irrigation water application management presented in the IWMP sufficient to minimize the potential movement of irrigation water below the root zone within application fields? *Alternative Outcomes:* • No action • Adjust irrigation methods and/or rates *Decision Statements:* 1. If the volumetric water content (VWC) or available water content (AWC) at the 3 foot below ground surface interval within an irrigation application field does not exceed the soil field capacity (FC) on a volume or weight basis, respectively, indicating that irrigation water application volumes and rates are not resulting in saturation of the soils and the potential for downward migration of irrigation water below the root zone, then no action is required.

	2. If the VWC or AWC at the 3 foot below ground surface interval within an irrigation application field exceeds the soil FC on a volume or weight basis, respectively, indicating that irrigation water application volumes and rates are resulting in saturation of the soils and the potential for downward migration of irrigation water below the root zone, then actions will be taken to adjust irrigation application rates and/or methods to appropriate levels to reduce VWC at the 3 foot below ground surface interval to or below the FC to minimize the potential migration of irrigation water below the crop root zone.
Step 3: Identify Inputs to the Decision	*Type of information needed (source in parentheses):* • Location and size of the application field (field records/GIS) • Soil properties and types within the application field (NRCS soil survey and field observations) • Topographic data for the application field that show low lying areas, swales, and drainages (field records, USGS maps, GIS, field observations) • Coverage rates and volumes for the various irrigation methods that may be employed within the field (Growers and irrigation equipment providers) • Water use and uptake properties of the various crops that will be grown in the application field (Land Grant University, AgriManagement documentation, and other publications) • Irrigation water order and delivery information (Irrigation district and growers) • Rainfall information (measured in the field) • Crop water use and evapotranspiration estimates (Outlook, WA – AgWeatherNet weather station) • Soil bulk density (samples collected prior to sensor placement) *Determination of Action Level:* • The action level will be based on the volumetric water content (VWC) and available water content (AWC) measured at 3 feet below ground surface. VWC will be compared with the location's soil field capacity (FC) on a volume and weight basis, respectively. VWC/AWC greater than the FC indicates conditions near saturation level of the soil beyond its water holding capacity and potential for migration of irrigation water below the root zone. *Appropriate Sampling and Analysis Methods:* • Soil Bulk Density – Soil bulk density is a common laboratory measurement. The collection of soil bulk density samples is simple and commonly performed during general soil sampling activities. Soil bulk density is a common analysis at soils laboratories. • Volumetric Water Content – Volumetric water content is a common parameter measured in agricultural settings, particularly in irrigated fields. Capacitance sensors are commonly used to measure volumetric

	water content in agricultural soils. Available water content will also be calculated as a secondary check parameter using VWC and soil bulk density data. • Applied Water Measurements – Input volumes can readily be measured using flow meters and calculations based on pump size and electricity use on irrigation application equipment. Field application will be calculated based on the type of application equipment (sprinkler and nozzle size, etc) and by use of tipping rain gauges located within the field. The tipping rain gauges will record both irrigation water as well as any additional water in the form of precipitation that is applied to the field. Manual rain gauges will also be located within the fields to provide verification of tipping rain gauge measurements. In the event that there are concerns regarding the uniformity of irrigation water application across the field, uniformity will be checked using a rain gauge grid evaluation within the field during irrigation.
Step 4: Define the Boundaries of the Study	*Target Population:* • The target population for the IWMP monitoring program is irrigation water within the soil column at 3 feet below ground surface in irrigated fields. The target population includes all electronic sensors that will be deployed at three feet below ground surface to adequately characterize the various field conditions and irrigation practices that are occurring within an irrigation application field. Additional electronic sensors will be deployed in the field to assist in developing appropriate irrigation water application rates and to provide information to the professional irrigation consultant regarding soil moisture conditions within the root zone. While it is anticipated that these sensors will provide valuable information regarding soil moisture conditions, they will not be used to evaluate the overall objective of the IWMP soil moisture monitoring program. *Spatial Boundaries:* • Horizontal – The irrigated area of the application field • Vertical – Soil moisture at 3 feet below ground surface (below the crop root zone). • Temporal – IWMP monitoring will occur during the irrigation season within fields that are being actively irrigated. *Practical Constraints on Data Collection:* • Irrigation Water Delivery – The ability to trigger immediate, automated irrigation system shutdown in the event that VWC/AWC exceeds FC is limited by the irrigation water delivery system used by the irrigation district. Based on conversations with the irrigation district Water Master, automated shutdown of individual irrigation systems within the main system could result in overflows within the system that could result in significant damage to irrigation laterals and potentially the larger canal system. The Water Master indicated that the irrigation district would not

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<td>allow the use of automated shutoffs for irrigation systems receiving water from the canals. The general process for irrigation water orders from the irrigation district is initiated weekly as follows:

Growers work with their agricultural irrigation consultant to determine the amount of water that will be required for the week.
Growers place an order requesting a certain amount of water to be delivered for a certain amount of time (this is a points systems where you can request a certain rate of water in cubic feet per second or gallons per minute)
When the order is made, the Water Master directs it to the Ditch Riders who fulfill the order by metering a certain amount of water through gates and valves to the appropriate canals and laterals.
Once the request for the order is made, the grower is obligated to take the amount of water ordered.
Some changes to the order can be made during the week, but take an unspecified amount of time to make and can only be accomplished during normal working hours.

Based on the restrictions on water delivery and ordering, soil moisture monitoring data will be evaluated on a weekly basis to coincide with water delivery and ordering systems developed by the irrigation district. Changes to irrigation methods and application rates will occur on a weekly basis.</td>
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<td>Step 5: Develop a Decision Rule</td>
<td>Population Parameter of Interest:

The primary parameter of interest (saturated conditions in soil at 3 feet below ground surface) will be determined using electronic sensors placed in representative areas within the irrigated fields. Secondarily, additional electronic sensors will be placed at select locations within the root zone at 1 and 2 feet below ground surface. These sensors will be used to evaluate root zone moisture conditions and to further increase surety that irrigation water application rates developed by the professional irrigation consultant are appropriate for crop and climatological conditions. However, these sensors will not be used to evaluate the overall objective of the IWMP soil moisture monitoring program. Given restrictions on the ability to provide immediate, automated shut off of irrigation equipment imposed by the irrigation district, irrigation schedules, water orders, and delivery amounts will be determined on a weekly basis based on the results of the previous week's soil moisture monitoring data and anticipated weather conditions.

Primary Decision Rule:

If VWC/AWC measurements at 3 feet below ground surface for the prior week are less than the soil field capacity, then a water order from the irrigation district will be made in accordance with the professional irrigation consultant's recommendations.
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<tr><td></td><td>If VWC/AWC measurements at 3 feet below ground surface for the prior week are greater than the soil field capacity, then the dairy will implement changes to irrigation application including changes to irrigation application rates, reduction in the water order, changes to irrigation methods, or other changes that will result in VWC/AWC less than the soil field capacity.</td></tr>
<tr><td>Step 6: Specify Tolerable Limits on Decision Errors</td><td>The IWMP soil moisture monitoring program is designed to provide sufficient coverage of soil moisture conditions at 3 feet below ground surface within representative areas of the application field. Representative areas will be determined based on NRCS soil types and their measured properties within the field; topographic relief of the field; the presence of low-lying areas, swales, or drainages; and the irrigation method used for the field. The soil moisture monitoring program focuses on those areas within the field that may be the most susceptible to the migration of irrigation water below the crop root zone (such as low-lying areas within soils with the greatest permeability).
Decision errors associated with the soil moisture monitoring program could result in the following:
Migration of irrigation water below the root zone (failure to detect over-application)
In order to minimize the potential impact associated with decision error, the soil moisture monitoring program focuses on the placement of monitoring points within areas that would be most susceptible to the migration of irrigation water, as noted above.</td></tr>
<tr><td>Step 7: Develop the Plan for Obtaining Data</td><td>Sampling Area Definition:
A total of 7 irrigated fields have been identified for the Cow Palace Dairy. The irrigated fields have been segregated based on the field location and irrigation method as shown in Table 1 and Figures 1 and 2. Also included in Table 1 is a brief summary of individual field conditions that have been used as a basis for data collection planning and monitoring design.
Description of Soil Types present in Irrigated Fields (from Soil Survey of Yakima County Area Washington, USDA Soil Conservation Service, May 1985):
Warden Silt Loam – USCS classification – ML. Very deep, well-drained soils, formed in lacustrine sediment with a mantle of loess, high available water capacity, permeability 0.6-2.0 in/hr.
Finley Silt Loam – USCS classification – ML/SM(shallow) increasing sand and gravel with depth – Very deep, well-drained soils, formed in old alluvium, low available water capacity, permeability 2.0 to 6.0 in/hr.
Scoon Silt Loam – USCS classification – ML,SM,GM. Shallow (typically less than 16 inches to hardpan), well-drained soils on uplands, formed in loess overlying hardpan, very low available water capacity, permeability 0.6-2.0 in/hr.
Shano Silt Loam – USCS classification – ML. Very deep, well-drained soils on uplands formed in loess, high available water capacity, permeability 0.6-2.0 in/hr.
Esquatzel Silt Loam – USCS classification – ML. Very deep well-</td></tr>
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	drained soils on flood plains, formed in silty alluvium, very high available water capacity, permeability 0.6-2.0 in/hr. • CP-SU-1 (Figure 3): Located to the south of the Cow Palace Dairy and west of Arms Road. The field is approximately 69 acres and is irrigated using a linear irrigation system. Soil types present include: o Warden silt loam (2-5 and 5-8 percent slopes) o Scoon silt loam (5-8 percent slopes) o Shano silt loam (8-15 percent slopes) o Finley silt loam (2-5 percent slopes) The general slope of the field is to the south. A y-shaped low-lying swale is present in the field in the eastern portion of the field with one branch of the “y” extending to the northwest and the other oriented north-south. Soil types within the low lying area are predominantly the Finley and Shano silt loam units with Scoon silt loam in the northwest portion of the “y.” • CP-SU-2 (Figure 4): Located at the northwest intersection of Kirks and Arms Roads south of Field CP-SU-1. The field is approximately 71.7 acres and is irrigated using a combination of linear and wheel line irrigation systems. Soil types present include: o Scoon silt loam (8-15% slopes) (Limited to the northwest corner of the field) o Warden silt loam (2-5, 5-8, and 15-30% slopes) The general slope of the field is to the south. A low-lying swale continuing from the field to the north (CP-SU-2) is present in the field and is oriented roughly north-south. The low-lying area exits the field to the southwest where any tail water is captured in an irrigation frost pond. • CP-SU-3 (Figure 5): Located south of Zillah Road between Arms and Dekker Roads. The field is approximately 155.4 acres and is irrigated using a center pivot irrigation system. Soil types present include: o Finley silt loam (2-5% slopes) (small area near northwest corner of field) o Warden silt loam (2-5, 5-8, 8-15% slopes) The general slope of the field is to the southwest. A lower-lying swale area is present in the western portion of the field trending northeast to northwest. The soil type associated with the swale is the Warden silt loam. • CP-SU-4B (Figure 6): Located south of CP-SU-3 to the west of Dekker Road. The field is approximately 71 acres and is currently irrigated using a wheel line irrigation system. Historically, rill irrigation has been used in this field when it was planted in corn. However, this practice has been discontinued. The only soil type present in the field is the Warden silt loam (2-5, 5-8, and 8-15% slopes). The general slope of the field is to the southwest. A low-lying swale area is present in the field trending from approximately the northeast corner to the southwest corner of the field. A frost pond is present along the swale in the southern third of the field. • CP-SU-4B (Figure 7): Located south of CP-SU-4A to the west of Dekker

	Road. The field is approximately 40.1 acres and is currently irrigated using a wheel line irrigation system. The only soil type present in the field is the Warden silt loam (2-5, 5-8, and 8-15% slopes). The general slope of the field is to the southwest. A low-lying swale is trending roughly north-south is present near the middle of the field. • CP-SU-5 (Figure 8): Located on the northeast corner of Zillah and Arms Roads. The field is approximately 37.1 acres and is currently irrigated using a wheel line irrigation system. The only soil type present in the field is the Warden silt loam (2-5 and 5-8% slopes). The general slope of the field is to the south. A lower-lying swale is present in the field extending from the northeast corner of the field to the center of the southern boundary of the field. • CP-SU-6 (Figure 9): Located on the north side of Knowles Road between Arms and Dekker Roads. The field is approximately 85 acres and is irrigated using a wheel line system. Currently, the field is planted in corn silage and is being irrigated using a rill irrigation system. This practice will be discontinued following the 2013 irrigation season. Soils present in the field include: o Esquatzel silt loam (0-2% slopes) o Warden silt loam (2-5, 5-8, and 8-15% slopes) The general slope of the field is to the south-southwest. In the eastern portion of the field, a lower-lying swale extends from the northeast corner to the center of the southern boundary of the field. This swale is located in both Warden silt loam and Esquatzel silt loam soils. Another lower-lying swale area extends from the farthest north point of the field to the southwest corner of the field. This swale is located in the Warden silt loam soil type. Sampling Design: A judgmental sampling design was used to identify the number and location of sensors that will be placed and monitored in each of the irrigated fields. The sensor placement focuses on those areas of the field that may be the most susceptible to the migration of irrigation water below the crop root zone (such as low-lying areas within soils with the greatest permeability). The number of sensors identified for placement in the field is based on the location and type of susceptible areas as well as the irrigation methods being employed. The number and proposed locations of sensors for each field are presented in Figures 3-9 and are summarized below. All sensors in all fields will be set to record the volumetric water content on an hourly basis. Sensor information will be recorded on a data logger and will be downloaded on a weekly basis. The data will be downloaded and analyzed prior to placement of the weekly water order with the irrigation district. The professional irrigation consultant will determine the volume and rate of irrigation water needed for the following week. The irrigation water volume and application rates developed by the professional irrigation consultant will be used by the dairy to place the water order with the irrigation district and to perform irrigation activities. • CP-SU-1 (Figure 3): A total of 3 sensors will be placed in CP-SU-1.

	o Near the northeast corner of the field in the swale (Warden silt loam) o In the southern portion of the swale (Finley silt loam) o In the southwest corner of the field (Warden silt loam) o No sensor was identified for placement in the northwest-southeast trending arm of the swale as this area is comprised of Scoon silt loam which only extends 16 inches before hard pan. • CP-SU-2 (Figure 4): Two sensors will be placed in CP-SU-2. o In the southern portion of the swale (Warden silt loam) o Near the northwest corner of the field (Warden silt loam) • CP-SU-3 (Figure 5): Three sensors will be placed in CP-SU-3. Only one soil type is present over the majority of the field (Warden silt loam). The sensors will be placed in near the beginning, middle, and end of the radius of center pivot irrigation system. The middle and end sensors will be placed in the north-south trending swale. • CP-SU-4A (Figure 6): Two sensors will be placed in CP-SU-4A. Only one soil type is present in CP-SU-4A (Warden silt loam). The sensors will be placed near the southern end of the northeast-southwest trending swale below the frost pond and in the center of the western portion of the field. • CP-SU-4B (Figure 7): Two sensors will be placed in CP-SU-4B. Only one soil type is present in the field (Warden silt loam). One sensor will be placed along the northern portion of the north-south trending swale and the other will be placed in the northwest quadrant of the field. • CP-SU-5 (Figure 8): Two sensors will be placed in CP-SU-5. Only one soil type is present in the field (Warden silt loam). One sensor will be placed in the north-south trending swale. The other will be placed in the southwest quadrant of the field. • CP-SU-6 (Figure 9): Three sensors will be placed in CP-SU-6. o In the northern portion of the field in the western swale (Warden silt loam) o In the middle of the field (Warden silt loam) o In the eastern swale (Esquatzel silt loam)